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A review on fuel economy standard for motor vehicles with the implementation possibilities in Malaysia

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ABSTRACT

This paper focused on a review of international experiences on fuel economy standard based on technologies available. It also attempts to identify savings possibilities and greenhouse gas (GHG) emissions reductions. It is known that road transport, particularly private cars are responsible for large, and increasing share of transport fuel use and emissions. With the implementation of fuel economy standard and label for motor vehicles, it will reduce the risks of increasing dependency on petroleum-based fuel and will increase the profit to consumers. The GHG emissions, which causing global warming, air pollution, diseases, etc. can be reduced as well. In this regard, advanced technologies such as, engine, transmission, and vehicle technologies may brought significant consumers and social benefits. Studies in developed countries have shown that fuel economy standard is beneficial for the society, government as well as the environment.

Contents

1. Introduction

Encouraging consumer towards better fuel economy standard vehicle will also help to reduce GHG emissions. Malaysia is one of the major vehicle users in Asia and therefore, ultimately the risks of increasing dependence on fossil fuel in this sector cannot be avoided within a short period of time. However, it is not only reason, but there are so many other matters such as increasing air pollution, global warming, health diseases, and etc that need to be taken into account seriously, It has been observed that one of the reasons of the increase in GHG emissions from passenger motor vehicles is due to the rise in the number of vehicles and kilometers traveled with lower fuel economy [1]. It is estimated that 25% of global CO_2 emissions from fossil fuels can be attributed to transportation, and over 30% in the Organization for Economic Co-operation and Development (OECD) countries [2]. This share will inevitably grow if current trends in transport sector energy demand continue and hence any consideration of limiting GHG emissions will need to be taken on board to the transport issue. Table 1 shows the transportation sector energy consumption for

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Table 1
The world's terminal energy consumption structure by region and sector (unit: mtoe).

Regions	Total consumption	Energy consumption by sector			
		Industry	Transportation	Agricultural/commerce/civil	Non-energy use
China	597	327 (54.8)*	80.5 (13.5)	165 (27.6)	24.5 (4.1)
USA	1597	394 (25.3)	623 (40.0)	475 (30.5)	65.4 (4.2)
EU (15)	1057	320 (30.3)	321 (30.4)	386 (36.5)	30.2 (2.8)
Japan	359	135 (37.6)	94.4 (26.3)	119 (33.2)	10.5 (2.9)
OECD	3692	1106 (30.0)	1242 (33.6)	1120 (33.0)	125 (3.4)
Total in the world	6212	2144 (34.5)	1831 (29.5)	2035 (32.8)	201 (3.2)

* Value inside the paranthesis is in (%). *Source*: Shunping et al. [3].

few selected countries. Fig. 1 shows emission trends for different models of transportation system.

The amount of CO_2 emitted from distance traveled is directly proportional to fuel economy, as every liter of gasoline burned releases about 2.4 kg of CO_2 [5].

The main objectives of fuel economy standard and label for motor vehicles can be considered as:

(i) To allow consumers to get more information in purchasing decisions on efficiency of motor vehicle.
(ii) To help in raising awareness in fuel economy standard of motor vehicles.
(iii) To encourage manufacturers to bring in motor vehicles with better fuel economy standard.

It promotes consumer demand for efficient vehicles by making comparative specific information of models available to buyers through fuel economy label. Therefore, it has been found that the technological and design changes in motor vehicles can help to increase GDP, create job opportunities, reduce oil consumption, and reduce emissions. In order to get verity of comprehensive results for fuel-efficient vehicles, the advanced technologies such as: engine, transmission, and vehicle technologies can be utilized [1].

2. Fuel economy standard in some selected countries

In order to provide guidance to consumers in their purchasing decisions on fuel-efficient vehicles, a simple and effective strategy is to introduce fuel economy standard and label. Standard set a fuel economy level of motor vehicles that manufacturers must meet in order to sell their products in market. In this respect, fuel economy standard have some advantages, because manufacturers may appreciate standard, as they reduce the market risk associated with introducing new products. On the other hand fuel economy label promote consumer awareness to purchase higher fuel efficiency vehicles and encourage manufacturers to produce more fuel-efficient vehicles. In this connection, many countries have

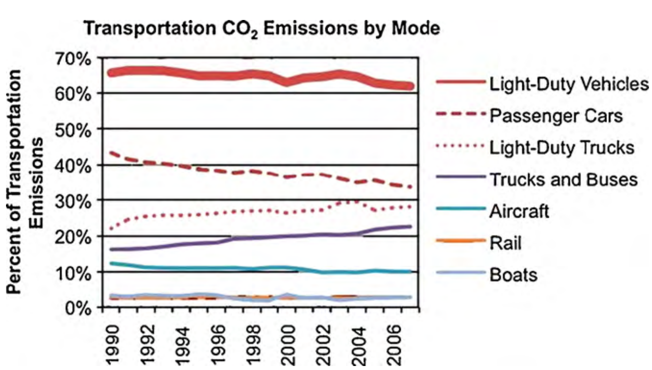


Fig. 1. Historical CO_2 emissions from the transportation sector (EIA, 2009) [2].

introduced fuel economy standard and label and others are planning to adopt the program. The primary policy for controlling motor vehicle fuel consumption in the United States is Corporate Average Fuel Economy (CAFÉ). This is the standard on the automobile fleet set, when the USA suffered the energy crisis created by the OPEC oil embargo of 1973–1974. It was estimated that this embargo caused the loss of 500,000 jobs and US$35–45 billions to the US gross national product [6]. In the aftermath of the crisis, US government began looking for ways to reduce the dependency on imported oil. Between 1973 and 1979, more than half a dozen major pieces of legislation related to energy policy were created. One of the policies enacted was the establishment of minimum acceptable standard for automobile fuel efficiency. Since the USA is a large automotive marketplace, policy actions governing fuel efficiency standard affected not only US manufacturers, but all vehicle manufacturers selling their product in the USA. Therefore, CAFÉ legislation had an impact on the economies of the European community and Japan. As the CAFÉ regulation has been successful at increasing automotive fuel efficiency standard over time, so the purpose of regulation to the time of its initiation was to help reduce reliance on foreign oil [7]. To determine the effectiveness of this goal it is necessary to examine the results of oil importation. In 1973 the USA imported 6.025 million barrels of oil per day. In 1992 this figure had only increased by 15% to 6.938 million barrels per day. During the same period, the number of registered vehicles in the USA increased from 126 million to 200 million an increase of 59%. The enhanced CAFÉ standard estimated through 2030 finds that such changes increase GDP and create 300,000 jobs distributed widely across states, industries, and occupation, reduce US oil consumption by 30 billion gallons each year, save drivers $40 billion, and reduce US GHG emissions by 100 millions tons [8].

In Canada fuel economy standard have been set by Transport Canada under voluntary Motor Vehicle Fuel Consumption Standard (MVFCS) program [9]. The program was designed to provide information on fuel consumption rates to vehicles buyers and to improve the fuel efficiency of new vehicle fleet. Under this program manufacturers are committed to meet annual corporate average fuel consumption (CAFC) standard. The Motor Vehicle Fuel Consumption standard (MVFCS) Act was passed in 1981 to enforce the CAFCS as part of the government's off-oil policy of the early 1980s. The conformity of technical standard is based on a "Self-Certification" system by manufacturers, as opposed to the European, Japanese and Australian system of "type approval".[1] Under self-certification system automobile manufacturers certify that every vehicle or vehicle part meet all applicable requirements. National trade marks and label are used to indicate that the vehicle

[1] Under the type-approved system, a national regulatory body certifies that a type of vehicle satisfies technical requirements as specified in relevant regulations, Each vehicle model, whether domestically produced or imported, is brought to the regulatory body for testing and to certify that it meets relevant technical requirements.

with Motor Vehicle Safety Act (MVSA). No company can import vehicles or equipment into Canada unless it confirms to the standard prescribed for its class.

In European Union, the forecast growth in fuel consumption by road transport is being a major policy challenge. In this connection the CAFÉ standard is an illustration of the importance that is attached to specific fuel efficiency of passengers car [10]. A voluntary agreement has also been signed by the European, Japanese and South Korean automobile manufacturers associations to increase the average fuel efficiency of their vehicles to 40 miles per gallon in 2008 and about 50 miles per gallon in 2012 [11].

The Chinese government is also preparing to impose fuel economy standard on new cars for the first time, and the rules will be more stringent than those in the United States, according to experts who were involved in drafting the regulations. China was a net oil exporter a decade ago, but the output has not kept up with soaring demand. It now depends on imported oil. The International Energy Agency predicts that by 2030, China's oil imports will equal the current imports of the United States, which gets 55% of its oil from abroad. So in this respect, the fuel economy standard are intended both to save energy and to compel automakers to introduce the latest technology in China, in hopes of easing the nation's swiftly rising dependence on oil imports from the Middle East. There are the latest and most ambitious steps to regulate China's rapidly growing auto industry, following moves, to require air bags for front-seat occupants in most new vehicles and require that new family vehicles solid in major cities meet air pollution standard nearly as strict as those in Western Europe and USA. The new standard would, in general, call for new cars to go as much as two more miles on each gallon of fuel than the average set in America. Large cars, for example, would be required to get 27.4 miles per gallon in 2005 and 30.4 miles per gallon in 2008, compared with the current US average of 27.2 miles per gallon [11].

3. Fuel economy and the global warming

Since the later half of the 1980s, global warming has been a prominent issue in international politics and 1980s became the decade of the global atmosphere. Predictions of widespread flooding as thermal expansion of the oceans was predicted to cause sea-level rise up to 1 m focused minds on global warming [12,13]. Emissions of GHG came under global control somewhat less rapidly as result of genuine scientific uncertainty concerning the magnitude of the problem combined with powerful lobbying by the fossil fuel industry. Next to many other sources, GHG emissions result from the transport sector also deserves serious attention. As of 1998, on road vehicles were believed to be the single largest source for the major atmospheric pollutants [14]. Transport sector has been considered one of the most significant contributors to a number of environmental and human-health problems, particularly, climate change acidification, ground level ozone formation, local air pollution and noise. In most OECD-countries, transport accounts for more than 25% of all GHG emissions [15].

In this connection there is mounting scientific evidence that human activities, particularly the burning of fossil fuels for electricity, industry and transportation are contributing to warming of our planet. Our atmosphere now contains 32% of more carbon dioxide – the principal global warming gas – than it did a century ago. The impacts of the build up of GHG in our atmosphere are already apparent. Global warming mean surface temperatures of the atmosphere have risen more than in the past century, and 1990s were the warmest decade on record, glaciers are melting, sea levels are rising, we are experiencing more frequent and intense storms and droughts, ecosystems, and habits are shifting, and species are going extinct at an unprecedented rate. The majority of climate scientists conclude that these trends will continue and worsen, with potentially disastrous consequences for the health of human beings, other species and the planet [16]. Transport is also widely recognized to be a significant and increasing source of air pollution world wide. It has been considered that road traffic exhaust emissions are the cause of much concern about the effects of urban air quality on human health and tropospheric ozone production. Several previous reviews have been focused on individual modes of transport and/or single environmental impacts of transport. The third International symposium on transport and air pollution has also emphasized on road traffic and urban air quality [17]. From the complete combustion of fuel, the significant transport emissions to the atmosphere by mass are CO_2 and water vapour (H_2O). In addition to the mixture of hydrocarbons, all fuels contain some impurities. Sulphur on combustion is oxidised mostly to sulphur dioxide (SO_2), and sometimes to sulphate which assist in the nucleation of particles in the exhaust. Several other impurities for example, vanadium in oil do not burn or have combustion products that have a low vapour pressure and so contribute further to particle formation.

In some parts of Africa and Asia, the organic lead compounds that are still added to high-octane petrol for preventing premature combustion, also form particles in the exhaust. Finally, at the high combustion temperatures of most transport sources of air pollution, atmospheric nitrogen (N_2) is oxidized to nitric oxide (NO) and small quantities of nitrogen dioxide (NO_2), in addition to smaller quantities from nitrogen-containing impurities in the fuel. Emissions from road traffic are being reduced substantially by the introduction of advanced technology and also, by local reduction measures. With a few exceptions, all modes of transport emit air pollution from the combustion of fossil fuels. Most transport sources today therefore emit similar pollutants, although the relative abundance of these varies depending on the exact composition of the fuel and details of the combustion conditions. In 1970s, it was suddenly noticed that trees were apparently dying in the highly polluted "Black Triangle" of East Germany, the Czech Republic and Poland [18–20] and numbers of dead fish floated to the surface of Swedish rivers and lakes [21] as well as similar in North American environments [22]. Initially, it was extensively use of coal in large combustion plant was to blame. International agreements such as: Geneva in 1979 and Helsinki in 1985 were held to cut emissions [23], next step to reduce air pollution emissions might have been replacement of fossil fuels with nuclear power. Finally, attention turned to private cars as source of oxides of nitrogen precursors to the increasingly significant atmospheric concentrations of nitric acid. Three-way catalytic converters to tackle emissions of oxides of nitrogen, hydrocarbons and carbon monoxide have been in use in Germany since 1984, 9 years ahead of European legislation to make such emissions control mandatory [23]. Sweden and Switzerland also introduced vehicle emissions standard ahead of the rest of Europe, in 1976 and 1982, respectively. Europe started to catch up with United States in control of emissions from road transport. It is also a fact that at European level, transport is expected to be the largest single contributor to EU GHG emissions by 2010. In this connection they are trying to achieve their target of about 8% reduction in GHG emissions by 2008-2012 under Kyoto Protocol [23,25].

Even though USA is more concerned for the fuel economy standard, but the passenger vehicles in the US is significant part of the global warming problem. It is known that USA is a home of about 4% of the world's population, but the USA is responsible for more than 25% of global GHG emissions. Cars and light duty trucks in the US are responsible for nearly 20% of annual US CO_2 emissions [27]. Infact, America's vehicles emit more CO_2 than the total national emission of all three countries namely China, Russia, and Japan [28]. Total CO_2 emission in selected countries is presented in Fig. 2.

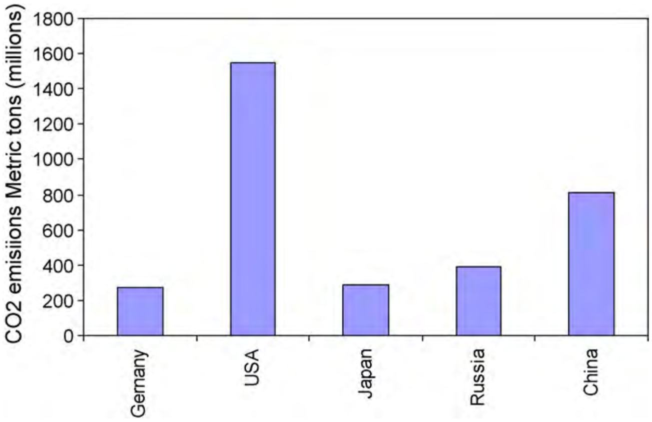


Fig. 2. Total emission in selected countries.

According to the Energy Information Administration (EIA) of the Department of Energy, CO_2 emission from the transportation sectors are growing faster than from any other end-use sector which is at 1.8% per year, while the residential, commercial and industrial are growing at 1.4, 1.6, and 0.9% per year, respectively, and overall CO_2 emissions are growing at an average rate of 1.4% per year [29]. In this respect, suitable decisions and measures must be taken in order to make this planet life able place for next generation. Everyone has the role to play in reduction GHG emissions that contribute to climate change, choosing a fuel-efficient car is one way to do this while saving money. This opportunity of reducing GHG emissions can be obtained by improving fuel consumption for conventional vehicles and introduction of alternative-fuel vehicles which will be discussed in the following section.

3.1. Improvement of fuel consumption for conventional vehicles

In this direction new advanced technologies are being developed and are coming into practical use, for example these technologies include lean-burn engines [30], direct-injected stratified-charge engine [31], and continuously variable transmission [32]. The study by references [30–32] assumes a 30% reduction in vehicular fuel consumption by using the technologies of both the direct-injected stratified-charge engine (20–25% reduction) and continuously variable transmission (10% reduction).

3.2. Introduction of alternative-fuel vehicles

In this respect, many kinds of alternative-fuel vehicles have been designed that use alcohol, natural gas, electricity and so on. Just taking the example of electric vehicles, the amount of CO_2 emissions from electric vehicles is influenced by the component ratio of the primary energies used in electric power plants. Referring to previous research analyzing the use of electric vehicles specially in Japan, assumes that the use of electric vehicles will reduce vehicular CO_2 emissions by 50% [33].

4. Effect of climate change on human health

The global environmental changes taking place have common origins in the scale and type of both ongoing and escalating human common activities. Population growth, the spread of industrialization and transport system, increased consumerism and the emergence of global economy are affecting the environment in ways that might not have been thought possible several decades ago. Concerted, coordinated action will be required to adapt and to mitigate the environmental and health consequences arising from these activities. As it has been observed that the presence of fine and ultra fine particulate matter in the air has become of increasing concern after epidemiological and clinical studies demonstrated an association between exposure and adverse health effects. According to the recent studies, it has been indicated that many of the population-related adverse health effects may be closely related to the presence of fine (<2.5 μm), and even more, to ultra airborne particles (<0.1 μm) [34–37]. These particles usually contain most of the trace elements and toxins and, due to their higher diffusion coefficients, penetrate deeper into pulmonary interstitial spaces in the lungs provoking inflammation [38]. This response is hypothesized to depend less upon the mass of the particles than on their number of and size distribution. In highly polluted urban environments that are significantly influenced by motor vehicle emission, number concentrations of particles nay exceed 10^5 cm^{-3}. In UK, it was found that particles number concentration was 7.5 times higher than the background near a busy road in Bristol [39]. The particles emitted by motor vehicles are mostly black carbon soot. They range in size from 0.02 to 0.13 μm form diesel engine [40] and 0.04 to 0.06 μm from petrol engine [41]. Motor vehicle emissions also contain nitrogen oxides and due to incomplete engine combustion, hydrocarbons and carbon monoxides. With the help of advanced technologies available, a significant reduction in gaseous and particle mass vehicular emissions can be obtained. Most of the ultra fine particles in an urban environment are originated from motor vehicles, these emissions are expected to have higher impacts on human health than emissions from other sources, and therefore it is important to develop a quantitative understanding of their contribution to particle concentrations in urban environments. As the industrial activities and transport systems have been considered the world's most serious causes of air pollution, and findings on both are fairly well documented in developed countries. In Tanzania, the department of Environmental Engineering of Ardhi Institute and other institutes has conducted a number of studies on air pollution and pertaining to both industrial and vehicular traffic sources. Despite the general feeling that environmental impacts of air pollution are generally known and well publicized. It is indisputably true that there is still a need to educate the public on effects which leave a direct bearing on their health and socio-economic welfare. In this respect, the most important environmental impacts include: effects on human health, effects on animal health, effects on vegetation and effects on materials and other socio-economic value. Effects on human health are manifested as respiratory diseases such as bronchitis whose correlation with air pollution is well established and documented. Lead poisoning is known to lead to kidney cancer and retardation of the central nervous system, arising from leaded petrol. Lead also affects both hemoglobin synthesis and red blood cells' survival times in the body. In vehicle emissions, CO also ends up putting a strain on the heart and impairing coordination. Nitrogen dioxide (NO_2) and nitrogen oxides (NO_x), all of which are gases emitted with fuel combustion products have been closely associated with occurrence of diseases such as: pharyngitis, bronchitis, tonsillitis, colds, and sore throat. Airborne particulates like ash, soot, dust and smoke also cause health hazards. The mucous epithelium, in man, traps much of the particulate matter but smaller particles can penetrate deep into the lung itself [42].

Growing awareness of climate change has stimulated several assessments of its likely effects on human population health. As the detection and attribution of early effects of climate change on the health of human population is a priority, so a range of anticipated health effects have been described. Some of the direct-acting effects are likely to become evident. For example, an increase in heat waves-related deaths and an increase in ultraviolet radiation-induced skin cancer in some population may occur soon or are already occurring. In affecting the plant growth and distribution,

there is already good evidence resulting from anthropogenic climate change. There is also good evidence of climate-related change in the distribution and behavior of animal species in Europe and elsewhere. If extreme whether events become more frequent (such as heat waves, floods and droughts), then delectability will refer mainly to whether the frequency of such events or exposure has increased. If such events become more or less serve, thus changes in the magnitude of the health effects associated with such events could be detected. This means that governments must take action to adapt to the potential or actual health and other effects of climate change. As we know that human-induced changes in global climate system and in stratospheric ozone pose a range of health risks. Irrespective of actions that might soon be taken to reduce or abate these environmental changes, human populations will be exposed to some degree of climate change and increased ultraviolet irradiation over the coming decades. Climate change is likely to have wide-ranging and potentially serious health consequences. In this direction, failure to reduce fossil fuel consumption (as the principal means of reducing GHG emissions) will result directly in continuing burden of mortality and disease from exposure in local air pollution. Managing risks to health requires several steps. Those are [43]:

(i) awareness that the problem exists;
(ii) an understanding of what causes the problem;
(iii) capacity to deal with the cause;
(iv) a sense that the problem is important;
(v) political will.

5. Improving fuel economy standard

Only 12.6% of original energy from the fuel conversion to the wheels provides acceleration, overcome aerodynamic drag and rolling resistance. The rest is lost; therefore because of this the potential to improve fuel economy with advanced technologies is enormous. Energy balance for a vehicle is presented in Fig. 3 [44].

Even modern internal combustion engines convert only one third of the energy in fuel into useful work. The rest of the energy is lost to waste heat, the friction of moving engine parts or to pumping air into and out of the engine. All of these steps at which energy is wasted are opportunities for advanced technologies to improve the fuel economy standard for motor vehicles. The technologies available are continually involving, and those currently available can be utilized more widely. As emerging Technologies, now in the late stage of development, and will like to be introduced over the next several years and will be increasingly utilized, and advanced technologies in the R&D stage could also become available over the next 10–15 years. A more complete discussion of these technical issues can be found in Refs. [45–48].

6. Available technologies

In order to improve the fuel economy of motor vehicle, the technical options can be classified as followed. These technologies and their associate costs and potential fuel efficiency improvement are summarized in the following Tables 2 and 3 [45].

6.1. Powertrain technologies

According to the National Research Council (NRC), the engine, transmission, and vehicle technologies listed here are likely to be available within the next 15 years [45]. Some (listed as production intent) are already available, and are well known to manufacturers and their suppliers, and could be incorporated in vehicles once a decision is made to use them; other (designated emerging) are generally beyond the R&D phase and are under development, and are sufficiently will understood that they should be available within 10–15 years.

6.2. Load reduction technologies

Load reduction technologies include mass reduction, streamlining, tire efficiency, and accessory improvements. The Office of

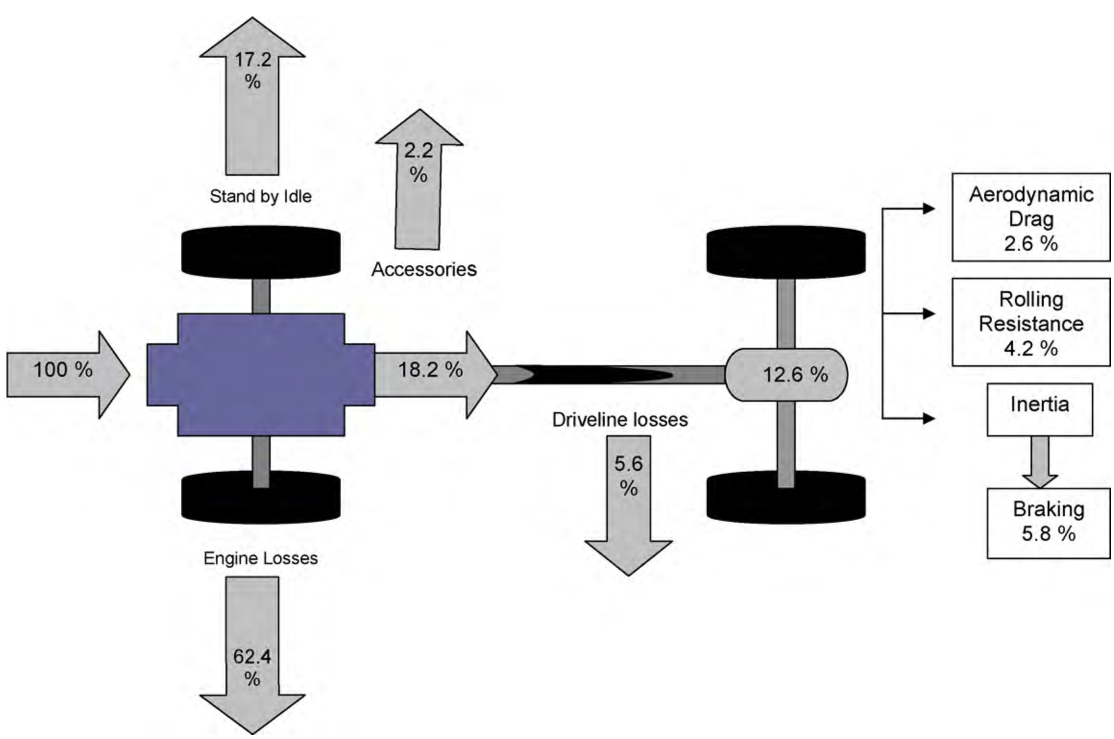


Fig. 3. Energy balance for a vehicle.

Table 2
Potential increase in fuel economy and price for production intent technologies.

Technology production intent	Fuel economy improvement (%)	Retail price increases ($)
Engine technologies		
Engine friction and other mechanical/hydrodynamic loss reduction.	1–5	35–140
Application of advanced, low friction lubricants.	1	8–11
Multi-valve, overhead camshaft valve trains.	2–5	105–140
Variable valve timing.	2–3	35–140
Variable valve lift and timing.	1–2	70–210
Cylinder deactivation.	3–6	112–252
Engine accessory improvement.	1–2	84–112
Engine downsizing and super charging.	5–7	350–560
Transmission technologies		
Continuously variable transmission (CVT).	4–8	140–350
Five speed automatic transmission.	2–3	70–154
Vehicle technologies		
Aerodynamic drag reduction on vehicle design.	1–2	0–140
Improved rolling resistance.	1–3.5	14–56

Technology Assessment (OTA) study found relatively good agreement among the major US, German and Japanese automakers on potential reduction in tractive loads [49]. OTA's conclusions about reductions, based on both the automakers views and a combination of literature review, interviews with suppliers and examination of prototype, are as given below:

(i) Drag coefficient from average of 0.33 down to at least 0.25, optimistically to 0.22, will give rise a gain in fuel economy 6–7%.
(ii) Rolling resistance from average of 0.008–0.010, down to about 0.005, will give rise a gain fuel economy up to 8%.
(iii) Regarding the weight, with steel (and aluminum engine), up to 15% reduction in curb weight; aluminum intensive (not optimized), 20% reduction; optimized aluminum, 30% reduction; with carbon fiber composites, up to 40% reduction, will give rise a gain in fuel economy 9–24%.

Because of more stringent requirements to improve fuel economy and emissions, there is growing trend to substitute light weight metals such as: aluminum (Al) and magnesium (Mg), which presents a major opportunity for weight reduction and other benefits when used to substitute conventional steel and cast irons in automotive applications. Material selection requires considerable information on physical/mechanical properties and the resultant products: reliability, manufacturing feasibility, and cost. The ability to design and optimize component weight-reduction opportunities effectively requires a complete understanding of how process, metallurgical structure, and properties interact. While designers and engineers have standard technical information and design criteria for traditional materials, application-specific information for the "newer" materials is still being developed. Now materials are considered for incorporation into vehicle designs if they provide benefits at an affordable cost. The cost of a new material is always compared to that presently employed in a product. It is one of the most important variables that determine whether any new material has an opportunity to be selected for a vehicle component. These Costs include three components which are actual cost of raw materials, manufacturing value added, and cost to design and test the product. This latter cost can be large since it is only through successful vehicle testing that the product and manufacturing engineers can attain a level of comfort to select newer materials for application in a high-volume production program.

Table 3
Potential increase in fuel economy and price for emerging technologies.

Emerging technology	Fuel economy improvement (%)	Retail price increases ($)
Engine technologies		
Camless valve actuation.	5–10	280–560
Variable compression ratio.	2–6	210–490
Intake valve throttling	3–6	210–420
Transmission technologies		
Automatic shaft/manual transmission.	3–5	70–280
Advanced continuously variable transmission.	0–2	350–840
Automatic transmission with aggressive shaft logic.	1–3	0–70
Six-speed automatic transmission.	1–2	140–280
Vehicle technologies		
42-V electrical system.	1–2	70–280
Integrated starter/generator (idle off-restart).	4–7	210–350
Electric power steering.	1.5–2.5	105–150
Vehicle weight reduction (5%).	3–4	210–350

Table 4
Fuel economy improvement of technological and design changes.

Technology	Impact (%)
Acceleration reduction.	10
Look-up torque converter for automatic transmission.	10
Five speed manual transmission.	5
Improved lubricants.	2
Reduced accessory loads.	2
Reduced aerodynamic drag.	4
Reduced rolling resistance.	3
Diesel engine[a]	20–25
Weight reduction (material substitution, front wheel drive, etc)	5
Improved spark-ignition engines[a]	2–10
Variable displacement engines[a]	3–7
Turbo chargers[a]	0–5
Domestic production of captive imports[a]	0–5
Sales-mix shaft to 10% large, 25% intermediate, 25% compact, 40% subcompact	5

[a] Not used to establish maximum feasible standard but considered a "safety margin".

In rule making that established a passenger car by CAFÉ standard in 1981 for 1981–1984, the US Department of Transport (DOT) evaluated manufacturers plan for downsizing and weight reduction along with the list of technologies. The DOT concluded that the goal of 27.5 mpg was feasible also set standard for intermediate years. The technology improvement and the impact are presented in Table 4 [50].

7. Implementation possibility in Malaysia

As the transportation has been considered one of the key factors for the economy and society, but unfortunately there are not many policies around the world that have been implemented for reducing transport sector energy use other than for motor vehicle or road transport. In this connection, there are many methods and policies have been implemented for road transport vehicles to reduce fuel consumption in developed as well as in many developing countries. These policies include fuel economy standards for motor vehicle, fuel economy labels, fuel switching, fuel taxation, emission abatement and further improvements to vehicles. Malaysia is comprised of West Malaysia (Peninsular Malaysia) and East Malaysia (Sabah and Sarawak). Total area of Malaysia is 330,242 $km^2$and its breakdown is given as



Fig. 4. Map of Malaysia.

Peninsular Malaysia	131,703 km^2
Sabah and Labuan	74,089 km^2
Sarawak	124,450 km^2

The map of Malaysia is given in Fig. 4.

According to the fourth report of the population and housing census 2000, the total population of Malaysia was 23.27 million compared to 18.38 million in 1991 thus giving an average annual population growth rate of 2.6% over the 1991–2000 periods [51]. After nearly a decade of strong economic growth averaging 8.7% annually, Malaysia was hard hit by the regional financial crisis of 1997–1999. The economy suffered a sharp 7.5% contraction in 1998 but rebounded in 1999 to grow by 5.6% for the year. In the 40 years thereafter, Malaysia's economy record had been one of Asia's best one. From the early 1980s through the mid-1990s, the economy experienced a period of broad diversification and sustained rapid growth averaging almost 8% annually. By 1999, nominal per capita GDP had reached $3238. New foreign and domestic investment played a significant role in the transformation of Malaysia's economy. Manufacturing grew from 13.9% of GDP in 1970 to 30% in 1999. The Malaysian Government encourages Foreign Direct Investment (FDI). Malaysia's New Economic Policy (NEP), first established in 1971, seeks to eradicate poverty and end the identification of economic function with ethnicity. In particular, it was designed to enhance the economic standing of ethnic Malays and other indigenous peoples (collectively known as "bumiputeras" in Bahasa Malaysia). Rapid growth through the mid-1990s made it possible to expand the share of the economy for bumiputeras without reducing the economic attainment of other groups at the same time. Malaysia has developed the automotive sector to help reduce the effects of volatile changes in rubber and palm oil prices on its economy, avoid having a huge trade deficit, and as a platform for economic development. The Malaysian auto market is dominated by Malaysia's national cars, Proton and Perodua, which in 1998, accounted for 90% of the vehicles sold annually [52]. Some 25 other manufacturers compete for the remaining 10%. In Malaysia the percentage of petrol vehicles is 89% and diesel vehicles are 11% and their growth rate is 9% per year. The breakdown according to vehicle type is as under [53]:

Motorcycles	50.5%
Passenger Cars	38.5%
Commercial Vehicles	11.0%

In Malaysia, the motor vehicle inspection for new vehicles is subjected to "type approval" inspection, which is conducted by examining the documentations submitted to Department of Environment (DOE) by the vehicle manufacturers or assemblers, and for in-use vehicles through periodical inspection, which is to be conducted at inspection centres [53].

Despite being self-sufficient in terms of oil and gas needs and being a member of the Association of South East Asia Nations (ASEAN), Malaysia has always given a high priority to oil security and emergency preparedness efforts. This explains Malaysia's commitment and ratification of the ASEAN Petroleum Security Agreement (APSA) 1986. In this respect, it is also very beneficial to Malaysia to introduce the fuel economy standard for motor vehicles, in order to have the solution to the oil dependence which always ties in technological progress such as developing advanced vehicle technologies that use energy more efficiently as Fig. 3 shows that all of the steps at which energy is wasted are providing opportunities for advanced technologies to increase fuel economy. By taking an interest in fuel economy standard and label, it can help to reduce gasoline and diesel consumption in Malaysia, reduce GHG emissions, create jobs distributed widely across states, industries and occupations, providing awareness to consumer to have decision power to purchase a vehicle with higher fuel economy standard and create incentive for motor vehicle manufacturers to produce cleaner, and more fuel-efficient vehicles in future. The Malaysian government heavily influences the activities of the domestic automotive manufacturers/assemblers because as a developing country, Malaysia believes that a strong motor industry brings employment, technology and prestige. Furthermore, many sectors in Malaysia will benefit from implementing this strategy. Therefore this work aims to give an initiative for Malaysia and as well as to other developing countries to implement fuel economy standard as soon as possible. While taking the advantage of advanced technologies listed in Tables 2–4 [45,50], a huge range of results can be obtained. The reduction in GHG emissions would also be result from application of the best available technology. With the implementation of fuel economy standard for motor vehicles, consumers can be educated to have more information in purchasing decisions.

8. Conclusion

The increasing demand for the transportation is one of the causes that lead to higher rates of growth in demand for oil. For most of the Asian countries, this growth expected to be more rapid than the growth of the economy as a whole. In order to reduce the dependence on oil, which is a common concern in Malaysia today,

it is very beneficial for Malaysia to introduce the fuel economy standard for motor vehicles. In long term, increasing consumer demand for fuel-efficient vehicles will encourage manufacturers to produce vehicles that are more efficient. This will continue to benefit consumers and environment. As automotive industries are intensely competitive and significantly influences the economic, environmental and human conditions of nearly every nation on the earth, therefore, the Malaysian government should encourage the manufacturers to produce more fuel-efficient vehicles. It should be noted that significant fuel economy improvement require major, comprehensive vehicle redesign and investments as well as have long lead times. A higher fuel economy improvement in manufacturer's new car will require a complete redesign of the engines, transmissions, accessories, tires and aerodynamics (meaning that body styles will also have to be redesigned), coupled with structural design and substantial materials substitution to reduce weight. Moreover, virtually every carline would have to be redesigned; it achieves a fleet-wide improvement. Such changes would have to be planned in advance and would require huge amount of capital investment. Through this improvement it is expected that the Malaysian automobile can exceed any tough fuel consumption standard set by some other countries. Finally, it is to be concluded that the consumers, manufacturers, government and environmentalist will get tremendous benefit by implementing the fuel economy standard and label for motor vehicles in Malaysia.

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